Innovative Prefabrication in Texas Bridges

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Texas has used prefabricated bridge elements for decades, but prefabrication's potential to reduce traffic disruption and improve constructibility has stimulated increasing bridge design innovation within TxDOT in recent years. TxDOT is developing new ways to incorporate prefabrication into bridge design as it responds to growing public demand for improved traffic flow in urban areas with minimal traffic disruption during construction.

Overwater Constructibility – Redfish Bay Project

Construction of a half-mile long bridge over Redfish Bay, a project ending in 1994, posed the challenge of overwater work on the Gulf Coast. The design included precast piling as well as a precast double-tee superstructure with 44 identical bent caps, which the contractor requested to precast.

Bent caps were fabricated in Corpus Christi and used epoxy-coated reinforcing to protect against corrosion in the marine environment. They were transported by barge to their location and then lifted into place over epoxy-coated reinforcing steel hairpin bars on the piling to form the connections. The interface between pile and cap was sealed, and concrete was placed through the slot in the top of the cap to complete the connection.

Minimized Traffic Disruption – US 290 Ramp G Project

TxDOT extended this constructibility innovation to solve a traffic disruption problem in work on a ramp for US 290 in 1994. After the contract had been let and work started, it became clear that formwork for the proposed cast-in-place cap would interfere with traffic and require closing of the ramp for an estimated 41 days. With TxDOT's approval, the contractor instead precast the straddle bent cap at the work site and lifted it into position. When it was in place, workers post-tensioned bars and grouted the cap-to-column connections. The ramp was closed to traffic for only 6 hours.

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Innovative Segmentals – Louetta Road Overpass Project

In the early 1990's TxDOT opted to use precast columns on its Louetta Road Overpass project in Houston. To increase durability of the new structure, designers for this project used high performance concrete, and they designed hollow column segments to take advantage of the 10,000 psi concrete. The column segments were stacked sequentially, the joints epoxy-bonded, and the columns post-tensioned together vertically after all segments were in place. The bottom segment was filled with concrete to protect it against possible vehicular impact.

Minimized Traffic Disruption – Pierce Elevated Project

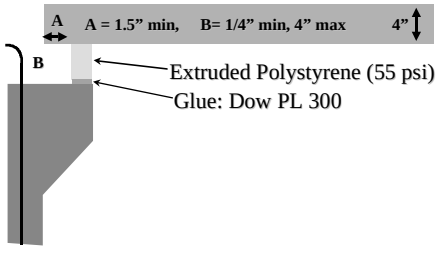
When a 113-span section of IH 45 in Houston's central business district needed replacing in 1996, designers estimated that a conventional bridge system would require more than a year and a half of construction. Estimating user delay costs at $100,000 a day, TxDOT opted to speed construction by using precast bent caps on the existing columns. Designers turned to the question of how to connect the precast caps to the existing columns. After discarding the idea of demolishing the top of the columns just enough to expose reinforcing steel, they decided to cut the caps off at the top of the columns and replace them with precast caps anchored with post-tensioning bars and hardware. Like earlier projects, this one used precast deck panels and concrete beams. The first deck unit was cast only five days after the start of demolition, with all construction finished in 95 days.

Recognizing increasing need for precast caps, TxDOT commissioned the Center for Transportation Research at the University of Texas at Austin to develop connection details for precast bent caps. Working closely with TxDOT, the Association of General Contractors, and a leading highway contractor, researchers developed constructible and efficient connection details appropriate for multi-column bridges with a relatively low bending moment at the top of the column. Details include anchorage of unheaded or headed reinforcing steel in grout pockets or grouted vertical ducts.

Cushioning for Precast Deck Panels – Many TxDOT Projects

A couple of decades ago, TxDOT adopted precast bridge deck panels, which act as a stay-in-place form for the cast-in-place part of the bridge deck and actually increase its ultimate strength. Designers initially used fiberboard to cushion the deck panel, but the fiberboard tended to deform in rain and restrict the flow of cast-in-place concrete between the panel and beam. A recent innovation is the use of foam instead of fiberboard. The dense foam resists moisture and allows concrete to flow underneath the deck panel to properly support the panel.

Supports Using Foam



Minimized Disruption – Dunlavy, Hazard, Mandel, and Woodhead Streets

In the mid-1990's widening of US 59 from six to ten lanes, including two high-occupancy-vehicle lanes, required replacement of bridges connecting streets in four Houston neighborhoods. Project challenges included neighborhood displeasure with proposed disruptions during on-site construction and restrictive clearances beneath the bridges. To maintain freeway traffic under the bridges and allow city street traffic over US 59 while removing and replacing the bridges, TxDOT provided attractive tied arch bridges, structures that suspend a thin slab from two tied arches 45 feet apart. The existing bridges were used as work platforms for erecting the arches, and the slabs were precast in segments and then bolted to erection beams to eliminate the need for falsework under the bridge during construction. This approach will soon be used on three more bridges.

Cap-to-Column Connections – Lake Ray Hubbard Project

After 40 years of service, the narrow two-lane crossing of SH 66 over Lake Ray Hubbard had become a congested route for commuters in the suburbs east of Dallas and needed to be replaced. In 2000, construction began on a pair of conventional prestressed concrete I-beam bridges with lengths of 10,280 and 4,360 feet. After the project was let for construction, the contractor asked to precast the substructure bent caps as an alternative to the original design of cast-in-place multi-column bents to reduce the amount of time the workers would need to operate near power lines.

Using design recommendations from the research stimulated by the Redfish Bay and Pierce Elevated projects, TxDOT designed a precast bent cap option that included a cap-to-column connection and a specific construction procedure. The connection design included reinforcing steel dowel bars that protrude from the columns into the precast caps via open ducts that are grouted after cap placement. On this project a total of 43 bent caps will be precast.

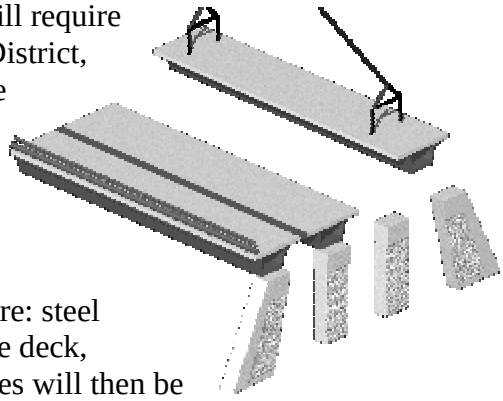
High-Moment-Demand Cap Connections – Lake Belton Project

The Lake Belton bridge replacement project is scheduled for letting in late 2002. Because of fluctuating water surface elevations on the lake and uncertainties about performance of underwater precast column joints, designers chose a cast-in-place twin column arrangement. The twin bridges will be 3,840 feet long with 62 identical precast interior bent caps. Planning for this project provided the opportunity to use research results from the study initiated during the Pierce Elevated project on precast bent cap connections for multi-column bridges. However, Lake Belton's hammerhead bents will be some of the highest-moment-demand cap-to-column connections used yet with precast caps, presenting new design challenges.

Bridge designers used test results from earlier research to develop design procedures extended for high-moment-demand connections. TxDOT has also funded a 2002 Research Implementation Project to adapt and implement guidelines for multi-column bent cap connections to single-column, high-moment-demand connections and to continue development of specifications addressing grout placement, segregation, and durability.

Minimized Traffic Disruption – Waco-5 Project

Reconstruction of IH 35 in the coming decade will require construction of nearly 200 bridges in the Waco District, and a primary goal for the project is to reduce the time that traffic is disrupted by lane closures and detours during construction. The first five bridges have been designed to use rapid field erection techniques.



This project will use a prefabricated superstructure: steel tub girders will be prefabricated with a composite deck, cast off the project site. The slab-girder assemblies will then be lifted into place in one operation. Narrow (16-inch), reinforced, cast-in-place, low shrinkage, low permeability concrete will connect the precast slabs to fully develop the deck.

This project contributes another innovation with its in-filled precast columns. Unlike the Louetta Overpass hollow segmental columns, columns for these five bridges will be full size, with a precast outer shell that will be erected over drilled shafts from which extend reinforcing steel. They will then be completely filled with cast-in-place concrete to complete the supporting substructure, eliminating the need for epoxy and post-tensioning.

TxDOT work on these Waco-5 bridges will provide information for two important research projects. TxDOT will conduct physical testing of the narrow cast-in-place slabs used to connect the precast slabs, gathering field data on the following:

- The magnitude of live-load bending moment and shear in the longitudinal connecting slab.
- The magnitude of live-load bending moment and longitudinal force in the transverse connecting slabs at the interior bents and abutment.
- The magnitude of bending moment and shear in the transverse connecting slabs at the abutment due to potential support settlement.
- Thermal shrinkage forces on the system.
- Fatigue effects on the system.

In addition, TxDOT has commissioned a study on the development of precast bridge construction systems from the Center for Transportation Research at the University of Texas at Austin. This research is intended to investigate the following:

- Grouting of precast connections.
- Use of hollow and structural lightweight concrete members.
- A system approach to precast bridge construction involving precast foundations, columns, bent caps, abutment caps, backwalls and wingwalls, and precast slab and rails.
- Precast slab panels with a cast-in-place topping.
- Use of precast box beams or precast double-tee beams.
- Schemes to accommodate horizontal and vertical alignment, cross-slope, skew, bridge length and width, and phased construction.

In addition to the Waco-5 bridges, the Lake Ray Hubbard and Lake Belton projects may also benefit from results of this study.

References

Gregg Freeby. “Evolution of TxDOT Prefabricated Bridge Construction.” Paper presented at 2001 Transportation Short Course. College Station, Texas. October 2001.

Gregg Freeby and Ronald Medlock. “Texas Prefabricated Bridge Systems: An Evolution in Bridges.” Paper presented at Transportation Research Board 2002 Annual Meeting. Washington, D.C. January 2002.

Kathleen Jones and Kenneth Ozuna. “Innovative Engineering Details to Connect Precast Concrete Bent Caps to Columns.” Paper presented at the Fall Meeting of the American Society of Civil Engineers, Texas Section. El Paso, Texas. October 2000.

E. E. Matsumoto, M. C. Waggoner, G. Sumen, M. E. Kreger, S. L. Wood, and J. E. Breen. “Development of a Precast Bent Cap System.” Research Report 1748-2, Center for Transportation Research, University of Texas at Austin. Austin, Texas. January 2001.

Brian Merrill. “Innovative Construction Methods for Texas Bridges.” Paper presented to graduate engineering class, Texas A&M University. College Station, Texas. October 2001.